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family resembles that of the astronomy of Hipparchus. Detached facts have been collected, hypotheses have in many cases been formed as to their relations and the laws governing them. In reference to any one of them the near or remote future may produce a Newton to demonstrate the fundamental law by a rigorous mathematical analysis. Meanwhile any laborer in the particular field who has the patience or skill to make an observation or an analysis or perhaps a contribution to pure mathematics may be entitled to his share in the triumph. Though the amount contributed be small there is a great satisfaction in feeling that your labors have been the means of adding something to the world's store of knowledge.

Mankind is no longer striving to evolve a universal science, or an all-embracing system of philosophy. We now recognize the fact that the same frontier which bounds our knowledge bounds also our ignorance, and as the area of the known increases, in the same ratio do the points of contact with the unknown. Every problem solved calls into being new ones for future struggles, and whether or not the universe is infinite, it is at all events for our purposes inexhaustible, so there is no lack of employment for all who may have the ambition to enter the field.

This society is especially designed to further the cause of science in the colleges and universities. As I understand the matter its most important function is that of offering encouragement and recognition to those who are about entering the arena of active life. We make no distinction between pure and applied science. Our purpose is to strive for the advancement of knowledge and the conquest of nature. The earnest student of truth will find his highest reward in the satisfaction which attends the discovery and recognition of the fundamental laws of nature and the essential

unity of all, with the consciousness that he has contributed something, however small the amount, towards a proper understanding of her mysteries.

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*THE IMPORTANCE OF A LABORATORY  
COURSE OF PHYSICS IN THE  
STUDY OF MEDICINE.\**

MANY medical colleges include in their teaching a course of physics, consisting of lectures illustrated by experimental demonstrations of important principles. Few give a laboratory course in which qualitative and quantitative experiments are made by the students themselves. In order to ascertain approximately how many medical colleges in the United State give laboratory courses of physics, letters were recently sent by the writer to about thirty-five medical institutions asking for information on the subject. Colleges were selected which by reason of standing, endowment, equipment, number of students, etc., were likely to employ the best and most modern methods of teaching. Answers from thirty were received. Only three colleges give the course in question. Some express regret that the course is not given, others hope to see it established.

The medical colleges which give the course are:

Barnes Medical College, St. Louis, Mo.

Dartmouth Medical College, Hanover, New Hampshire.

Medical Department, University of Virginia, Charlottesville, Va.

To this number should be added:

The College of Physicians and Surgeons, Columbia University, New York City.

There are at present approximately 160 medical colleges in the United States, of which only 122 are so-called regular schools, the others being homœopathic,

\* Read before the Society of the Alumni of Bellevue Hospital, February 5, 1902.

eclectic, physiomedical, etc.\* If the proportion of answers received be taken as a ratio, then ten per cent. of these colleges give a laboratory course of physics. Probably five or six per cent. is a more correct estimate.

Among those that do not give the course are the following:

Cornell, Harvard, Johns Hopkins, Tulane, Rush Medical College (University of Chicago), University of Pennsylvania, and Yale.

The object of this paper is to show that a laboratory course of physics is important in the study of medicine, and also to point out that a course of much value can be completed in a comparatively short time, provided the experiments are properly selected and certain methods of instruction are carried out.

#### THE IMPORTANCE OF LABORATORY WORK.

The laboratory method of instruction has been recognized as essentially important in scientific, technical and engineering schools, and has grown in favor continually during the last twenty years. It has been adopted in medical colleges in many subjects, including anatomy, chemistry, physiology, and others, where it is also acknowledged to be essential.

Dr. C. S. Minot, of Harvard, in his address at the Yale University Medical Commencement in 1899, spoke thus of the laboratory:† 'Knowledge lives in the laboratory,' and again, 'Our greatest discovery in scientific teaching is the discovery of the value of the laboratory and its immeasurable superiority to the book in itself.'

'A lecture is a spoken book, and must, therefore, also yield to the superior claims of first-hand knowledge.'

In physics, laboratory work should be an organic part of a systematic course, and

\* 'Report of U. S. Commissioner of Education,' Vol. 2, 1898-99.

† 'Knowledge and Practice,' C. S. Minot, SCIENCE, July 7, 1899.

the course should consist of lectures, of experimental demonstrations by the lecturer, and of qualitative and quantitative experiments performed by the students themselves. Such a systematic course has been given to the first-year students of the College of Physicians and Surgeons, Columbia University, since 1893, when it was organized by the Department of Physics at the request and with the cooperation of the Faculty of Medicine. The laboratory part of this course is in charge of the writer and is described below:

#### THE LABORATORY COURSE OF PHYSICS FOR MEDICAL STUDENTS AT COLUMBIA UNIVERSITY.

The course consists at present of twelve periods of laboratory work of three hours each, followed by a final written examination on the salient points of the experiments performed in the laboratory. At the beginning of the course an introductory lecture is given, in which the object of the course, the methods to be followed, the rules for note-keeping, etc., are fully explained. At the same time, each student is provided with a suitable notebook and a printed form called the 'course-list,' containing a list of selected experiments. The course-list also contains a blank column in which is entered the date when each experiment is performed. The course-list is pasted in the front of the notebook and is of service as an index of the notes in the book. Another printed form, the 'time schedule,' is pasted in the back of the notebook, and in this the student is required to keep a record of each attendance. The time schedule is a help to the student in apportioning his time to the experiments in the course. The attendance is also entered on a general time sheet posted in the laboratory for purposes of laboratory record.

*Rules for Note-keeping.*—The principal rules for governing note-keeping are as follows: The notes must be a synopsis of the actual work performed and not a description of the experiment. They must be entered in pencil at the time when the experiment is performed, and in accordance with a simple form adopted. Also, they must be accompanied by diagrams illustrating the work, and systematic tabulations of the observations made in the experiments.

*The Experiments Performed by the Medical Students.*—Each student performs twenty-five experiments, twenty of which are prescribed and five of which he himself selects from the remaining experiments on the course-list. The prescribed experiments have been selected for the purpose of illustrating the important principles of physics which are of value in the study and practice of medicine. These experiments are divided between mechanics, heat, light and electricity. The present list is as follows:

**Mechanics and heat:**

1. Measurement of distances, inch and millimeter scales.
2. Measurement with the vernier.
3. Measurement with calipers and micrometers.
4. The barometer; reducing the reading to zero temperature C.
5. The analytical balance; weighing by swings and interpolation.
6. The Mohr balance; density of liquids.
7. The thermometer; correction of the boiling-point mark.

**Light:**

8. Focal length of a convex lens (three methods).
9. Focal length of a concave mirror (three methods).
10. Microscope; magnifying power (two methods).
11. Microscope objectives; tests for spherical and chromatic aberrations.
12. The spectrometer; complete adjustment.
13. The spectrometer; measurement of the angle of a prism.

14. The spectroscope; spectra of metals.
15. The spectroscope; absorption spectra of liquids.

**Electricity:**

16. Measurement of resistance by the substitution method.
17. Measurement of resistance by the difference of potential method.
18. Measurement of resistance by the Wheatstone bridge.
19. Measurement of electromotive force by the high resistance method.
20. Measurement of current by the voltmeter and the ammeter.

Approximately 160 medical students take the laboratory course each year. On account of this large number it has been found necessary to divide the class into four sections, which attend the laboratory on different days.

**SYSTEM OF INSTRUCTION.**

Time for completing experiments can be economized by proper direction of the instructor in charge and by proper appliances. In the present case, twenty-five experiments are performed in thirty-six hours, which is less time than is generally allotted to that number of experiments; yet perfectly satisfactory work is done by the medical students. This result is accomplished by the system of instruction employed, which is as follows: To each experiment is assigned a special table in the laboratory on which is permanently kept a set of the requisite apparatus. After the students have attended the introductory lecture they go from one experiment to another until they have completed the list. During the periods of laboratory work, there is one instructor to about every ten medical students, who is constantly giving instruction and directing the work.

*Experiment Directions.*—Typewritten experiment directions, concise and illustrated by diagrams, are used also, and so placed on the tables that students may easily re-

fer to them. The text of each experiment direction is divided into two parts, each part being subdivided into several paragraphs, as follows:

First part:

- (a) Object of the experiment.
- (b) Theory and general explanation of the experiment.
- (c) Description and explanation of apparatus used.
- (d) Sources of error, precautions, etc.

Second part:

- (e) Practical instructions, giving method in detail.
- (f) Example, showing the form of entry of notes required in the notebook.
- (g) Explanatory notes, references, etc.

#### GENERAL UTILITY OF THE COURSE IN MEDICINE.

The course is of value to the student as a means of understanding the great principles of physics that are intimately related to medicine. It has also an additional educational value of a more general nature. Some of the teachings of the physical laboratory are enumerated below. No argument is necessary to emphasize their importance.

The experiments show:

1. The necessity of working with method and with deliberation.
2. The value of precision and the cost of carelessness.
3. The necessity of taking every factor of an experiment into consideration and of attaching proper importance and significance to each.
4. The liability of making mistakes in method and errors in manipulation.
5. The limitations of accuracy in both experimenter and instrument.
6. The significance with respect to mankind of physical properties, forces and laws.

These important points are brought to the notice of the student by even a short course of quantitative experiments in physics, and we maintain that in no other way are they shown with such clearness. The medical student is apt to slight his general scientific training and to devote his en-

tire energies to acquiring only that technical knowledge which he considers will be of 'practical' use to him in his profession. Thorough technical knowledge is necessary, but scientific training is equally important, for only through it can technical knowledge be applied to advantage. Medicine is every day becoming more of an exact science. Those of its departments in which progress has been rapid have demanded and received aid from physics, chemistry and biology.

#### PRACTICAL UTILITY OF THE COURSE IN MEDICINE.

The laboratory course, besides teaching scientific methods and fundamental laws of physics, has also a value that is distinctly practical for many physical instruments are used in medicine. The physician and the surgeon, moreover, are constantly called upon to devise special appliances, demanding of them a knowledge of physical manipulation and construction that can be acquired only in the laboratory.

As medicine becomes more of an exact science, the tests used in the diagnosis of diseases must be quantitative, requiring instruments of precision, having scales, verniers, micrometers and other measuring devices. Such instruments are used in medicine for the purpose of obtaining exact results. Some of these are enumerated below: The thermometer is one of the most constantly used instruments in medical practice. Clinical thermometers are used for determining body temperature, where an accuracy of at least one fifth of a degree is required; yet frequently they are found to have errors of a whole degree, the chief source of error being due to gradual change in the glass. It is therefore imperative that the physician should have a thorough scientific understanding of this important instrument and the modes of testing it. To the microscope is due the

greatest advancement in medicine. It has been the means of discovering bacteria and showing the minute cells of the body tissues. Accurate medical diagnosis now requires that the bacteria and cells must be counted and measured, demanding of the physicist a further improvement of this essential instrument. The spectroscope has been used recently for the analysis of blood and presents a field for medical discovery.

Many physical instruments have been adapted to the uses of medicine and have been given special names.

The cyrtometer for measuring the curves of the chest, and the æsthesiometer for determining the sensitiveness of the skin, the cardiometer, and the pelvimeter are all only calipers of different designs. Hydrometers and certain graduated vessels are called lactometers, saccharometers, or albuminometers to indicate their special uses. The spirometer, which measures the capacity of the lungs, is usually a modified form of gas meter. The sphygmograph, which records the pressure of the blood, is a registering pressure gauge. The hæmoglobinometer, for measuring the amount of hæmoglobin in the blood, depends on a photometric comparison. In general surgery, levers, screws, clamps, pumps and other mechanical devices are used in many forms. In orthopædic surgery in particular complicated mechanical appliances are employed. These consist of clamps braces and screws which are put together in a variety of combinations. A special appliance is often required for each orthopædic case, requiring of the surgeon a knowledge of the principles of mechanics.

In the study of the ear the tuning fork is used for producing uniform waves of sound, and the acoumeter for measuring the acuteness of hearing, the manometer and the otoscope for observing and testing the mobility of the aural membranes. In

the study of the eye a special photometer is used for determining sensitiveness to light, the ophthalmometer for measuring corneal images, the perimeter for measuring the field of vision, and the astigmometer for determining the amount of astigmatism.

*Applications of Electricity.*—The applications of electricity in medicine are increasing daily. In electro-therapeutics the direct and alternating currents have been used for many years, and recently the high voltage discharge from the static machine has proved valuable for the treatment of certain diseases. Electricity is used for cauterization, for eradicating tumors by electrolysis, and for illuminating the interior of the body in surgical operations. It is used in the production of X-rays, which are constantly employed in both medical and surgical diagnosis. No little electrical knowledge is required to operate X-ray apparatus. This knowledge must be practical as well as theoretical. In performing the electrical experiment in the physical laboratory the student uses, and becomes familiar with, various kind of batteries, different types of galvanometers, resistance boxes, switch keys, and various other forms of electrical apparatus. Some of this apparatus is always encountered when an electrical current is used. These are but examples showing the practical utility of a laboratory course of physics in medicine.

*In Conclusion.*—The study of medicine is long and difficult, especially when two years of hospital service are superadded to the course before private practice is begun; yet if a laboratory course of physics can be made of much value, the short time spent on it, for example thirty-six hours, seems a comparatively small part of the three or four years of study that are required in medical schools. In 1899 the total amount of work demanded of medical

students, in order to qualify for the M.D. degree, in 26 out of the 156 institutions in the United States was 'over 4,000 hours.\*' Inasmuch as the minimum requirement established by the Association of American Medical Colleges in June, 1899, was 'at least 3,300 hours,' it can be assumed that the 26 colleges mentioned above include the institutions of highest standing.

A laboratory course of physics of 36 hours, such as the one given at Columbia University, represents less than one per cent. of the total work required on the 4,000 hour basis.

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*SOME PRELIMINARY EXPERIMENTS ON THE  
MOTION OF IONS IN A VARYING  
MAGNETIC FIELD.*

THE experiments described below were suggested by the negative results of V. Crémieu's search for a force acting on a static charge in a varying magnetic field.† The scheme of the Crémieu experiment may be briefly described by the statement that a disc which was charged to a high potential was suspended in the field of a strongly excited electromagnet. Upon breaking the current the disc should have experienced a force in accordance with the Maxwell equation

$$\text{Curl } E = -\frac{1}{E} \frac{\partial H}{\partial t}. \quad (1)$$

The quantity of electricity that can be placed on a body of considerable dimensions is comparatively small, so that in the case of the Crémieu experiment  $e/m$  was a small quantity.

It occurred to me to use the negatively charged ions in an ionized gas as the car-

riers of the static charge; in the case of ions  $e/m$  is very large, being about  $4 \times 10^{17}$  E.S. An ion, because of its high charge, should move with considerable velocity in a varying field of moderate strength. For the purpose of showing the theoretical magnitude of such ionic motion in such a field I will assume an ideal case. Suppose that a cylindrical vessel is placed in a coil of a few turns through which is passing an oscillatory current of high frequency. Assume that there is a complete vacuum except for one negative ion which at the initial time is at rest at a distance  $r$  from the center of the coil. The ion will be acted upon by a force the direction of which will be a circle of radius  $r$  about the magnetic center of the coil. Neglecting the centrifugal acceleration and the change in apparent mass due to its motion, if the maximum strength of the field at the position of the ion is 100 C.G.S. and the frequency is  $10^6$ , it may be shown that the ion would execute a harmonic oscillatory motion in a circular path around the center, with a maximum displacement from the position of rest of 20 cm. and a maximum velocity of  $13 \times 10^7$  cm. per second.

Since for the purpose of experiment, it is desirable to have ions in abundance and a rapidly varying magnetic field, I have made use of the well-known electrodeless discharge in the Tesla oscillatory field, as in this form of discharge the gas is highly ionized and the field is of high frequency. In the actual phenomena the amplitude is of course many times smaller than that calculated above. The ions probably move but a short distance and are then stopped by collisions with the molecules, producing by the collision many other ions which by impact produce yet others and thus the effect accumulates until a strong current, the ring discharge, is produced.

To demonstrate by experiment that some such motion actually exists I have made

\* 'Education in the United States,' N. M. Butler.

† Crémieu, *Annales de Chimie et Physique*, 7th Series, I., 24.